Water Conservation of the Kangaroo Rat, *Dipodomys ordii*

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WATER CONSERVATION OF THE KANGAROO RAT, *DIPODOMYS ORDII*

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Kangaroo rats (*Dipodomys* spp.) have long been known for their water-conserving abilities. *Dipodomys ordii* is the most widely distributed kangaroo rat in the United States and its range extends through many climates. Five *D. ordii* from the Nebraska Sand Hills were used in this experiment. The results of this study indicate that *Dipodomys ordii* is not independent of free water, but does have a urine concentrating ability comparable to *D. merriami*, a desert-dwelling species. The individuals showed variability in their response to water deprivation.

† † †

INTRODUCTION

This study was designed to compare water conservation of *Dipodomys ordii* from the Nebraska Sand Hills (average annual precipitation 53 cm/yr) to water conservation of *D. merriami* and *D. agilis* as reported by Carpenter (1966). Heteromyid rodents have been studied for their adaptations to arid climates, much of the work being done with *Dipodomys merriami*, a kangaroo rat inhabiting the Mohave Desert (Schmidt-Nielsen et al., 1948; Schmidt-Nielsen, 1964; Carpenter, 1966; Bradley and Mauer, 1971; Grubbs, 1980). Carpenter (1966) demonstrated a difference in water-conserving abilities of *D. agilis* and *D. merriami*. He attributed this difference to the relatively mesic environment of *D. agilis*: 23 cm/yr average precipitation in the Tehachapi Mountains of California compared to 11 cm/yr in the Mohave Desert for *D. merriami*.

D. ordii columbianus drinks free water if it is available and the amount consumed varies greatly between individuals but is very consistent within individuals (Howell and Gersh, 1935). One individual drank 8.0 ml of water consistently while another individual drank only 2.0 to 2.5 ml (Richter, as cited by Howell and Gersh, 1935).

Grubbs (1980) concluded that the laboratory environment in which experiments on osmolarity of urine were conducted did not bias the results. He compared osmolarity of urine from *D. merriami* in the field to those in the laboratory, but found no significant difference.

MATERIALS AND METHODS

Animals

The study was conducted from January through March 1981. Five kangaroo rats (*Dipodomys ordii*) were caught in Nebraska National Forest near Halsey, Nebraska, in October 1980. The animals were caught at night with insect nets on the sand roads of the park. The kangaroo rats were kept in individual plastic cages with wire-grated tops. The cages were filled with 10 to 13 cm of sand and fitted with water bottles with L-shaped drinking tubes. During the entire experiment, the animals were given commercial gerbil mixtures of seeds and pellets *ad libitum*. The water content of the commercial gerbil mix was determined by drying a known weight of the food to constant weight in a drying oven. The water content was taken as the percentage of weight lost by drying. The food used in this study had a water content of 8%.

The relative humidity, measured with a Taylor sling psychrometer, of the room in which the animals were kept was 51%.

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Water Balance

The first experiment was to determine whether a positive or negative water balance exists when kangaroo rats are deprived of water. They were given water *ad libitum* for 3 wk while adjusting to the new diet and living conditions. Each rat was weighed daily to the nearest 0.1 g. The initial weight was taken to be the weight on the last day of *ad libitum* water. At the end of the stabilization period, all water was taken away from the five test animals for 13 days. During this period, they were fed *ad libitum* and weighed daily to 0.1 g. Weight was calculated as a percentage of initial weight each day of water deprivation. Following 13 days of water deprivation, the kangaroo rats were rehydrated for 1 mo.

Urine Osmolarity

Urine was collected from two rats on *ad libitum* food and water. Two of the kangaroo rats were put in metal cages with a wire-mesh floor. The cages were fitted with a tray that slid underneath the cage. This tray was filled with a layer of mineral oil to prevent evaporation of the sample before osmolarity tests could be run. The kangaroo rats were left in these cages for 24 hr. While in the cages, they were provided with a small amount of food, but no water. A Precision Osmette osmometer was used to determine the concentration of the urine sample. Because of the small size of the samples, 20 μ 1, they were diluted to 2:1 with distilled water before being tested in the osmometer which uses a freezing point depression method. Three trials were averaged for each sample tested. The kangaroo rats were then put back in their original cages and deprived of water for 9 days. The 9th day, the same two kangaroo rats spent 24 hr in the metal cages. However, only one yielded a sample that could be tested. All kangaroo rats were given *ad libitum* water again.

RESULTS

As seen in Figure 1, the kangaroo rats immediately began to lose weight when deprived of water. For the first 3 days the average weight loss was about 3% of the initial body weight. On days 4 and 5, the average was constant. Beginning on day 6, there was a 1% weight loss per day until water was returned to them on day 13.

It was noted that, although the kangaroo rats normally were easily handled, they became increasingly hyperactive. The two kangaroo rats that had lost the largest percentage of their weight became frantic in trying to escape while being transferred from their cages to the weighing cage.

On day 13, three of the kangaroo rats were given water. The two that had lost the least amount of weight were put

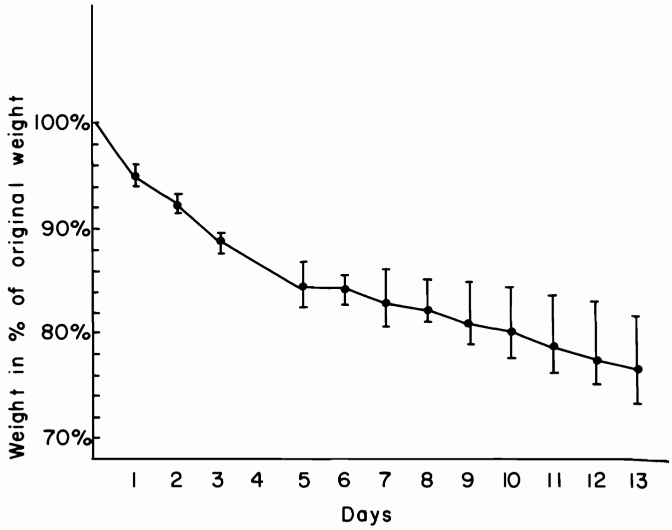

FIGURE 1. Average weight changes in five kangaroo rats (*Dipodomys ordii*) during water deprivation. Vertical lines indicate range of individual weight changes.

into metal cages in an attempt to obtain urine samples for osmolarity tests. After 24 hr, there was a drop of urine in the mineral oil from one kangaroo rat, but it was completely crystalline. The other yielded no sample, and both animals were returned to their original cages with water.

After a 4-wk period of rehydration, the two animals that had lost the least percentage of body weight in the previous part of the experiment were again put into the metal cages for 24 hr. Both produced urine samples large enough to be tested in the osmometer. The average concentration was approximately 550 mOsmols/1. The two kangaroo rats were put back in their original cages and deprived of water for an additional 9 days. On the 9th day, the animals were again put in the mesh-floor cages to obtain urine samples. Only one of the kangaroo rats produced a sample, the concentration of which was 4290 mOsmols/1.

DISCUSSION

Water Balance

In this study, the kangaroo rats, *Dipodomys ordii,* were unable to maintain a positive water balance when deprived of water.

As shown in Figure 1, the range of the individual weights was small in the beginning, but increased by the end of the experiment. This reflects the variability among individuals in their response to water deprivation. Howell and Gersh

(1935) found that the amount of free water consumed by *D. ordii columbianus* varied greatly between individuals, but that each individual was very consistent in the amount of water it drank, an indication of individual genetic variability.

Carpenter (1966) reported *D. merriami* to be completely independent of free water whereas *D. agilis* had a water requirement. He attributed this to the more mesic conditions encountered by *D. agilis*. *D. ordii*, inhabiting the Nebraska Sand Hills, would also be thought to have a water requirement. The results of this study indicate that *D. ordii* is not independent of free water.

Schmidt-Nielsen and Schmidt-Nielsen (1951) demonstrated the importance of humidity in the water balance of kangaroo rats on a dry grain diet. They found that *D. merriami* was able to maintain a positive water balance in relative humidities above 10%. In the present study, *D. ordii* was unable to maintain a positive water balance at about 51% relative humidity.

Schmidt-Nielsen and Schmidt-Nielsen (1950) gave evidence that the humidity in the burrows of *D. merriami* was significantly higher than the critical point needed to maintain water balance. In the present study, *D. ordii* attempted to "build" burrows in the sand. During the last period of water deprivation, one of the animals was able to form an enclosure about ¼ the size of its cage. This room was completely enclosed with no entrance. The kangaroo rat stayed inside this room for several days. When water was returned to the animal, a small hole was made in the wall of the enclosure which the kangaroo rat immediately filled. When the enclosure was disturbed again, the animal repeated this behavior. Sealing the

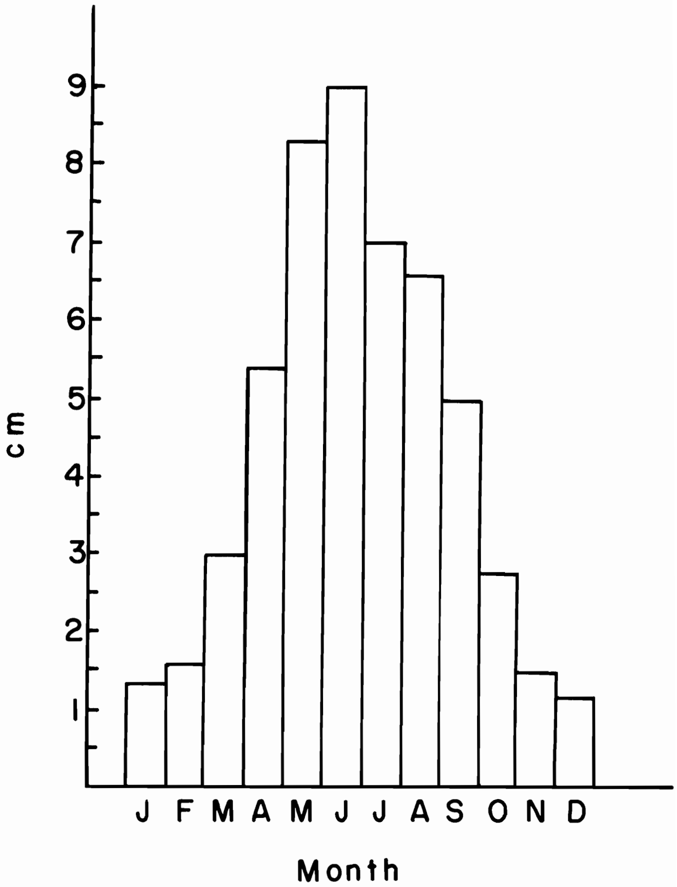

FIGURE 2. Average monthly precipitation at the Nebraska National Forest, Halsey, Nebraska, averaged over the years 1941-1970. (*From* Climatological data, Nebraska annual summary. 1980. National Oceanic and Atmospheric Administration, Asheville, North Carolina. Vol. 85, No. 13.)

TABLE I. Water conservation data on three species of *Dipodomys*.

Species	Location	Average annual precipitation	Water requirement	Urine osmolarity (mOsmols/1)	Source
D. merriami	Mohave Desert	11 cm/yr	no	4,000	Carpenter (1966)
D. merriami	Mohave Desert	11 cm/yr	no	est. 5,500	Schmidt-Nielsen (1964)
D. agilis	Tehachapi Mountains (Southwest California)	23 cm/yr	yes	3,200	Carpenter (1966)
D. ordii	Nebraska Sand Hills	53 cm/yr	yes	4,300	Present study

entrances of their enclosures may be an evolved behavior which enabled kangaroo rats to avoid dehydration.

Urine Osmolarity

When deprived of water for 9 days, the average osmolarity of urine was 4290 mOsmols/1. Table I compares osmolarity of urine from four studies on three species of *Dipodomys.* In view of these previous studies, the concentrations obtained for *D. ordii* are surprisingly high. On the other hand, *D. ordii* must be somewhat of a generalist in order to survive in the Mohave Desert as well as in the Sand Hills of Nebraska. This concentrating ability would definitely be an advantage in very arid conditions.

The monthly precipitation averaged over 30 yr (1941–1970) at the Nebraska National Forest is shown in Figure 2. During the drier months, free water may be unavailable for significant periods. Also, because of the geology of the Sand Hills, water is absorbed very rapidly into the ground so that standing water may not be available. This would select for strong water-conserving abilities. However, precipitation does occur monthly in the Nebraska Sand Hills making periods during which free water is unavailable shorter than might be expected in southern California. Therefore, individuals with a lower tolerance to dehydration are able to survive, possibly explaining the individual variability shown in this study.

Carpenter (1966) commented on the crystals in the urine of kangaroo rats. He found crystals even in urine taken directly from the urethral opening, indicating they are not due to evaporation. The completely crystalline sample from the present study was probably due to the extreme dehydration of the animal.

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